

Supplemental Data for:

Tian T, Ruppel M, Osborne J, Tomasino E and Schreiner RP. 2022. Fertilize or supplement: The impact of nitrogen on vine productivity and wine sensory properties in Chardonnay. *Am J Enol Vitic* 73:156-169. doi: 10.5344/ajev.2021.21044

Supplemental Table 1 Dates when soil nitrogen (N) (UAN) or foliar N (urea) fertilizers were applied to Chardonnay grapevines in 2016 to 2018.

	Date of application			Number of days after bloom		
	1 st application	2 nd application	3 rd application	1 st application	2 nd application	3 rd application
2016						
Soil N ^a	13 May	30 June	29 July	-19	29	58
2017						
Soil N	30 May	19 July	25 Aug	-23	27	64
Foliar N ^b	18 July	16 Aug	8 Sept	26	55	78
2018						
Soil N	31 May	20 July	-	-17	33	
Foliar N	18 July	10 Aug	6 Sept	31	54	81

^aUAN was applied at a rate of 17.8 kg N/ha (20 pounds N/acre).

^bUrea was applied at a rate of 8.2 kg N/ha (7.3 pounds N/acre) in 2017 and 7.4 kg N/ha (6.6 pounds N/acre) in 2018.

Supplemental Table 2 Vine phenology and meteorological variables for Chardonnay grapevines from 2016 to 2018.

Year/Growth stage	GDD > 10°C ^a	Mean daily temp (°C)	Precipitation (mm)	Total solar radiation (MJ/m ²)
2016				
Budbreak to bloom — 6 April to 1 June	336	15.0	81	1056
Bloom to veraison — 2 June to 12 Aug	672	19.0	41	1742
Veraison to harvest — 13 Aug to 15 Sept	354	20.0	3	748
Season total	1331		126	
2017				
Budbreak to bloom — 20 April to 22 June	383	14.9	102	1209
Bloom to veraison — 23 June to 26 Aug	761	21.4	3	1638
Veraison to harvest — 27 Aug to 28 Sept	323	19.1	42	541
Season total	1466		147	
2018				
Budbreak to bloom — 21 April to 17 June	365	15.3	43	1215
Bloom to veraison — 18 June to 22 Aug	762	21.3	0	1715
Veraison to harvest — 23 Aug to 26 Sept	217	16.7	15	609
Season total	1344		58	

^aGDD, growing degree days. To calculate GDD, the daily maximum and minimum temperatures were obtained from the Agrimet weather station at Aurora, OR. On occasions where the daily minimum temperature was below 10°C, it was adjusted to 10°C prior to calculation.

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Supplemental Table 3 Effect of vineyard N applications (Soil N and Foliar N) on leaf SPAD values of Chardonnay grapevines from 2016 to 2018. Vines that received no N supply (No N) served as the control. Values are means (standard deviation) for each treatment on each measurement day (n = 4).

Date	SPAD of opposite cluster leaves ^a			SPAD of upper canopy leaves ^b		
	No N	Soil N	Foliar N	No N	Soil N	Foliar N
2016						
13 May	35.1 (0.7)	35.2 (0.9)	-	-	-	-
30 June	35.3 (1.7)	36.9 (1.9)	-	-	-	-
18 July	34.5 (2.5)	36.9 (1.9)	-	-	-	-
5 Aug	30.6 b ^c (1.2)	35.1 a (1.1)	-	-	-	-
12 Aug	30.5 b (3.6)	35.8 a (2.8)	-	32.5 b (1.2)	37.6 a (1.8)	-
2017						
25 May	26.8 (2.2)	27.8 (1.3)	26.8 (2.2)	-	-	-
12 June	31.8 (3.7)	37.9 (2.0)	31.9 (3.7)	-	-	-
22 June	33.8 (2.8)	37.9 (2.2)	34.8 (2.8)	-	-	-
19 July	34.5 b (1.7)	39.4 a (1.8)	34.5 b (1.7)	31.5 (2.2)	35.2 (2.0)	-
4 Aug	33.1 b (1.7)	39.0 a (1.6)	35.3 ab (2.5)	31.7 b (1.0)	36.0 a (1.4)	32.0 b (1.4)
28 Aug	33.0 b (4.2)	42.3 a (2.9)	34.4 b (3.9)	32.6 b (1.9)	40.6 a (1.9)	33.5 b (1.7)
26 Sept	29.8 b (1.5)	40.2 a (1.3)	31.9 b (1.4)	30.4 b (3.2)	39.1 a (3.0)	30.9 b (2.7)
2018						
16 May	28.3 b (0.3)	30.9 a (0.6)	28.0 b (0.9)	-	-	-
31 May	29.9 (1.2)	32.1 (2.0)	28.8 (2.3)	-	-	-
18 June	34.5 (2.8)	37.8 (2.9)	32.9 (2.6)	-	-	-
24 July	33.3 (2.7)	37.2 (2.1)	33.2 (2.4)	-	-	-
10 Aug	32.5 b (1.7)	39.6 a (1.2)	32.4 b (1.2)	33.1 b (0.9)	40.2 a (0.8)	33.8 b (1.3)
23 Aug	31.2 b (2.8)	39.1 a (2.8)	31.0 b (2.1)	33.1 b (2.7)	40.0 a (2.0)	33.9 b (2.2)
25 Sept	24.0 b (2.8)	35.8 a (1.8)	25.0 b (2.3)	28.3 b (1.7)	36.8 a (0.8)	28.8 b (1.0)

^aLeaves that are opposite the clusters.

^bLeaves that are most recently fully expanded on the main shoot, or located at least two nodes below the hedging point of the shoot.

^cData were analyzed separately for each sampling date and leaf type (n = 4). Means followed by a different letter in a row for each leaf type differ significantly based on Tukey's honest significant difference test at 95% confidence.

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Supplemental Table 4 Effect of vineyard nitrogen (N) applications (Soil N and Foliar N) on leaf photosynthetic rates in Chardonnay grapevines between 2016 and 2018. Vines that received no N supply (No N) served as the control. Values are means (standard deviation) for each treatment on each measurement day (n = 4).

Date/Time	Leaf photosynthesis ^a (μmol CO ₂ fixed/m ² sec)		
	No N	Soil N	Foliar N
25 July 2016, 1500 hr	16.7 (2.0)	16.2 (3.8)	-
21 June 2017, 1500 hr	20.2 (2.4)	22.3 (1.7)	-
28 July 2017, 1500 hr	10.6 (4.0)	10.6 (5.0)	-
31 July 2018, 1500 hr	13.9 (1.1)	14.5 (3.2)	14.8 (1.4)
6 Sept 2018, 1200 hr	15.3 b ^b (1.7)	20.3 a (1.7)	15.4 b (2.3)

^aMeasurements were conducted on sunny cloudless days, when the ambient level of photosynthetically active radiation was >1700 μmol/m²/sec. Data were analyzed separately for individual measurement days.

^bMeans followed by a different letter in a row differ significantly based on Tukey's honest significant difference at 95% confidence.

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Supplemental Table 5 Effect of soil nitrogen (N) applications on leaf water potential on individual measurement days in Chardonnay grapevines between 2016 and 2018 (n = 4). Vines that received no N supply (No N) served as the control. Seasonal average is the mean of leaf water potential for each treatment after pooling data from all measurement days for each year.

Date	Leaf water potential (MPa)	
	No N	Soil N
2016		
20 July	-0.98 (0.08)	-0.99 (0.03)
22 Aug	-1.28 (0.10)	-1.33 (0.10)
12 Sept	-1.28 (0.24)	-1.53 (0.17)
28 Sept	-1.02 (0.18)	-1.26 (0.10)
Seasonal average	-1.14 a ^a	-1.28 b
2017		
12 July	-0.80 (0.05)	-0.86 (0.12)
26 July	-1.10 (0.10)	-1.17 (0.04)
28 July	-0.99 (0.07)	-1.04 (0.15)
9 Aug	-1.31 (0.24)	-1.39 (0.16)
28 Aug	-1.45 (0.12)	-1.47 (0.11)
12 Sept	-1.48 (0.21)	-1.56 (0.21)
14 Sept	-1.06 (0.14)	-1.16 (0.10)
Seasonal average	-1.17	-1.23
2018		
31 July	-1.26 (0.14)	-1.26 (0.13)
6 Aug	-1.14 (0.07)	-1.32 (0.17)
22 Aug	-1.36 (0.09)	-1.49 (0.11)
5 Sept	-1.36 (0.12)	-1.39 (0.13)
Seasonal average	-1.19 a	-1.37 b

^aData were analyzed for each experimental year after pooling data from all measurement days. Means followed by a different letter in a row differ significantly based on t-test at 95% confidence interval. Leaf water potential did not differ between the No N and + Soil N treatments on any individual measurement days. Irrigation was not initiated until the beginning of July in all years. Standard deviation is shown in parentheses.

Supplemental Table 6 Effect of vineyard nitrogen (N) applications (Soil N and Foliar N) on cluster zone solar exposure in Chardonnay grapevines near veraison from 2016 to 2018. Vines that received no N supply (No N) served as the control. Values represent means (standard deviation) for each treatment on each measurement day (n = 4).

Date/ Time	Cluster exposure (% PAR in cluster zone) ^a		
	No N	Soil N	Foliar N
27 July 2016			
930 hr	45 ^b (3.1)	51 (5.1)	-
1120 hr	33 (8.3)	38 (10.8)	-
1320 hr	2 (1.0)	2 (0.4)	-
1520 hr	24 (3.1)	33 (6.1)	-
1720 hr	44 a (11.2)	26 b (6.9)	-
11 Sept 2017			
1000 hr	60 ab (3.8)	50 b (5.1)	66 a (7.2)
1200 hr	31 a (6.8)	13 b (3.8)	22 ab (9.5)
1400 hr	32 a (6.1)	22 b (2.7)	38 a (4.8)
1600 hr	56 (9.6)	42 (4.7)	50 (9.5)
5 Sept 2018			
1000 hr	56 (6.1)	46 (3.4)	64 (6.1)
1200 hr	30 (17.3)	20 (11.9)	31 (13.7)
1400 hr	26 ab (8.0)	22 b (9.5)	31 a (12.5)
1600 hr	57 (6.1)	44 (7.3)	57 (7.9)

^aPAR, photosynthetically active radiation (400 to 700 nm). Basal leaves on the east aspect of the canopy were removed to improve cluster exposure prior to measurement, but leaves on the west aspect of the canopy were not removed. Measurements were performed in the east aspect of the canopy before 1300 hr and in the west aspect of the canopy afterwards.

^bData were analyzed separately for each time point on each measurement day. Means followed by a different letter within each row differ significantly based on t-test or Tukey's honest significant difference test at 95% confidence.

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Supplemental Table 7 Effect of vineyard nitrogen (N) application (Soil N or Foliar N) on must nutrient concentrations in Chardonnay grapevines from 2016 to 2018. Vines that received no N supply (No N) served as the control. Values represent means (standard deviation) for each treatment (n = 4).

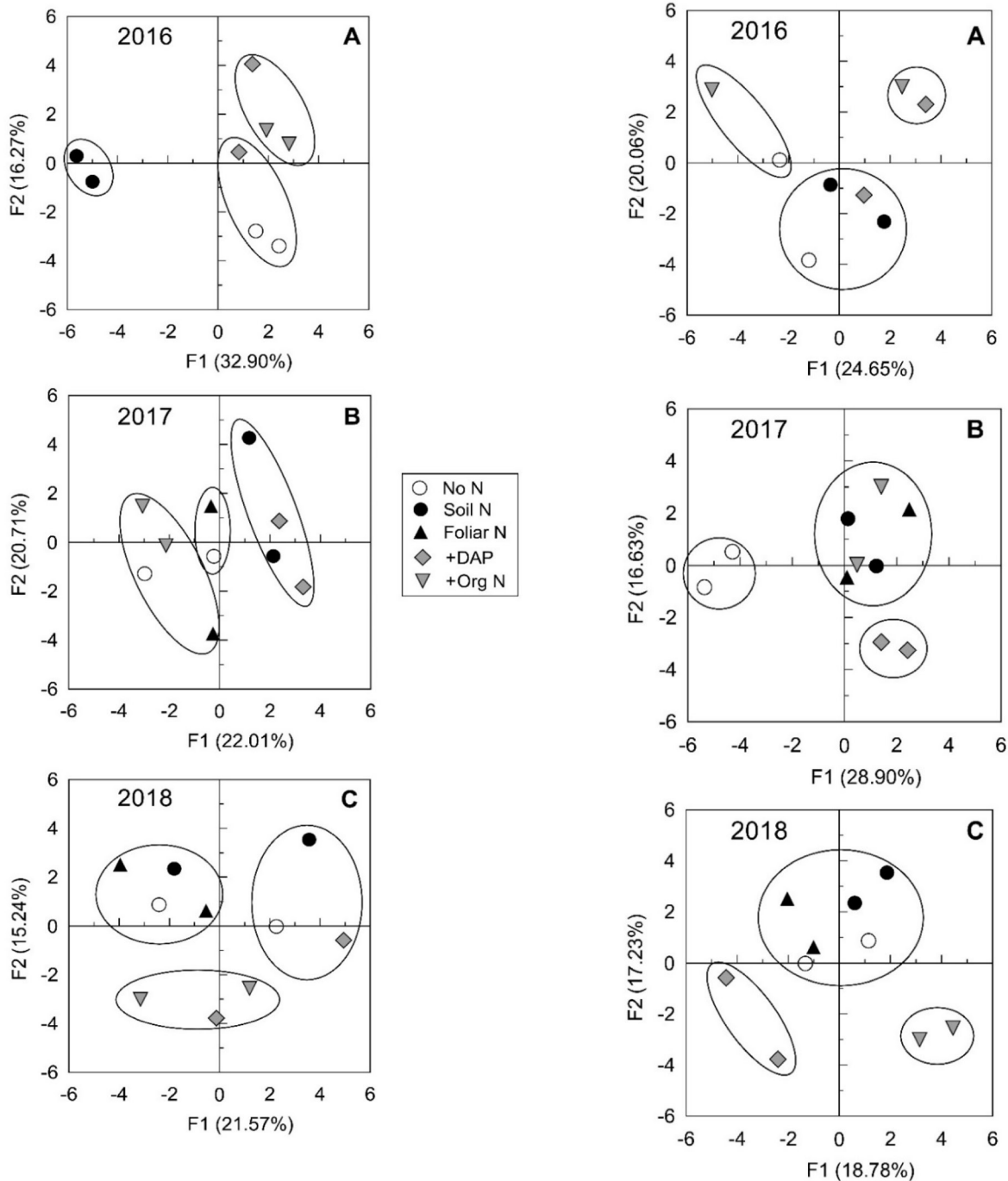
	B^a	Ca	Cu	Fe	K	Mg	Mn	Na	P	S	Zn
2016											
No N	2.9 (0.2)	79 b ^b (9)	1.0 (0.3)	3.1 (1.3)	751 (72)	74 b (5)	0.6 (0.2)	2.4 (0.7)	105 (14)	48 b (5)	0.5 (0.10)
Soil N	3.1 (0.2)	103 a (11)	1.1 (0.3)	3.0 (0.6)	836 (109)	97 a (4)	0.7 (0.2)	3.2 (0.8)	103 (7)	74 a (5)	0.5 (0.05)
2017											
No N	1.5 (0.1)	71 (3)	-	0.8 (0.6)	492 (27)	67 (3)	0.5 (0.2)	-	94 a (12)	45 b (4)	0.3 (0.08)
Soil N	1.3 (0.1)	61 (6)	-	0.4 (0.5)	541 (95)	62 (8)	0.4 (0.3)	-	57 b (10)	57 a (3)	0.2 (0.08)
Foliar N	1.5 (0.1)	64 (5)	-	2.5 (0.8)	516 (85)	64 (5)	0.6 (0.3)	-	87 a (13)	48 b (2)	0.2 (0.04)
2018											
No N	2.9 (0.6)	115 a (7)	0.5 (0.2)	1.2 (0.3)	959 (175)	74 a (3)	2.7 (0.2)	1.4 b (1.4)	98 a (10)	51 (7)	0.6 (0.11)
Soil N	2.5 (0.5)	88 b (9)	0.4 (0.1)	0.7 (0.2)	790 (238)	64 b (4)	2.5 (0.1)	1.0 b (0.9)	70 b (13)	55 (5)	0.5 (0.19)
Foliar N	3.3 (0.3)	94 ab (4)	0.4 (0.1)	0.9 (0.3)	785 (132)	71 ab (3)	3.0 (0.1)	4.0 a (0.7)	102 a (8)	52 (5)	0.6 (0.34)

^aConcentrations of all nutrients are expressed as mg/L.

^bData were analyzed separately for each year. Means followed by a different letter between treatments differ significantly based on student t-test or Tukey's honest significant difference test at 95% confidence.

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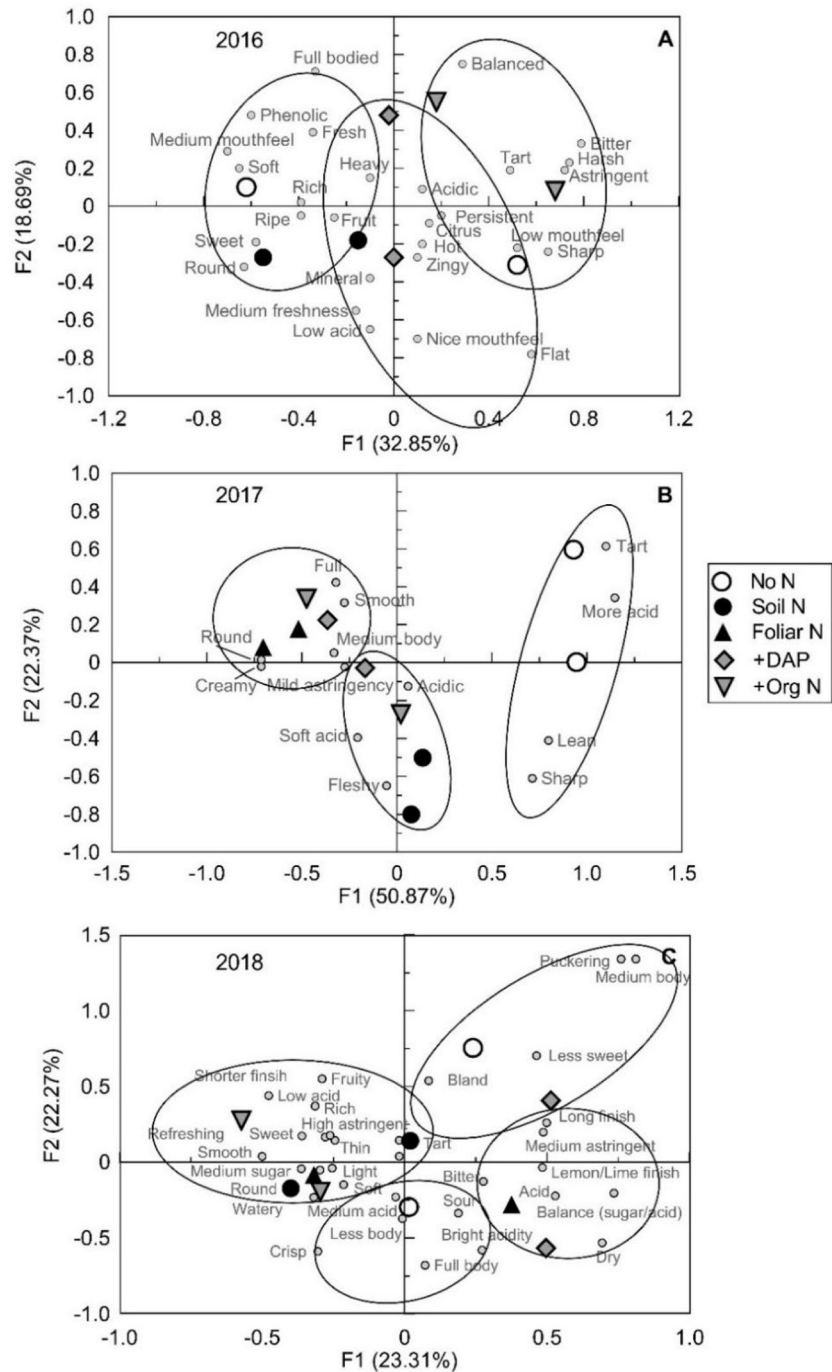


Supplemental Figure 1 Multiple factor analysis of Napping data for aroma of Chardonnay wines that received vineyard nitrogen (N) application (Soil N or Foliar N), winery N supplementation (+DAP or +Org N), or no N input (No N) between 2016 and 2018. Ellipses indicate groupings calculated using k-means clustering. Two samples of each wine were evaluated in each session.

Supplemental Figure 2 Multiple factor analysis of Napping data for mouthfeel of Chardonnay wines that received vineyard nitrogen (N) application (Soil N or Foliar N), winery N supplementation (+DAP or +Org N), or no N input (No N) between 2016 and 2018. Ellipses indicate groupings calculated using k-means clustering. Two samples of each wine were evaluated in each session.

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Supplemental Figure 3 Correspondence analysis of ultra-flash profiling data for mouthfeel in Chardonnay wines that received vineyard nitrogen (N) application (Soil N or Foliar N), winery N supplementation (+DAP or +Org N), or no N input (No N) between 2016 and 2018. Ellipses indicate groupings calculated using k-means clustering. Two samples of each wine were evaluated in each session.